An Ecological Study of the Soil Microfungi in a Hawaiian Mangrove Swamp[1]

BENNY K. H. LEE[2] AND GLADYS E. BAKER[2]

FOR MANY YEARS a large number of investigators have considered the ecology and physiology of mangrove swamps, but there are still many gaps in our knowledge about mangrove communities as pointed out by Clark and Hannon (1967), Walsh (1967), and Macnae (1968). Microorganisms have received less consideration than other organisms. Marathe (1965) worked with algae and several microbiologists have studied fungi: Swart (1958) in East Africa; Cribb and Cribb (1955, 1956, and 1960) in Australia; Kohlmeyer and Kohlmeyer (1965), and Kohlmeyer (1968, 1969*a, b*) on both sides of the Atlantic Ocean and the central Pacific Ocean; and Rai, Tewari, and Mukerji (1969) in India. With the exception of Kohlmeyer's work (1969*a, b*), there have been no studies of mangrove-associated microfungi in Hawaii. Neither the macrovegetation of the mangrove swamp nor its soil fungal communities have received much attention in Hawaii, possibly because mangroves are recently introduced plants (Walsh, 1967) but more probably because comparatively few studies have been made of fungi in Hawaii (Kohlmeyer, 1969*b*).

This investigation is a study of Hawaiian mangrove soil as a habitat for microfungi and an ecological analysis of the swamp macrovegetation.

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THE STUDY AREA

The Heeia mangrove swamp is located at the mouth of Heeia stream which flows from the Koolau mountain range on the northeastern side of Oahu. The swamp extends some 350 meters along the banks of the stream toward the ocean. Inland, the swamp connects with a freshwater, grassy marsh which is populated mainly by *Paspalum* sp. On its eastern edge, the swamp is bordered by the Heeia fish pond which in turn connects with the ocean through a channel at its northern border (Fig. 1).

Trade winds and topography are the principal causes of climatic variation on the island of Oahu. The Heeia mangrove swamp, which is on the windward side of the island, lies more or less perpendicular to the prevailing trade winds. Rainfall and cloudiness are very high and there is considerable rain during winter and summer (Price, 1966). From May to September, the trade winds provide most of the rainfall for the islands; during the winter months, occasional storms provide most of the rain. The mean annual rainfall in this area is about 50 inches. The relative humidity commonly averages 75 percent. Temperatures are equable. The mean annual temperature is about 25° C (76° F) (Price, 1966).

Two mangrove genera, *Rhizophora mangle* L. and *Bruguiera sexangula* Lour., and the so-called "freshwater mangrove," *Hibiscus tiliaceus* L., occur in the Heeia swamp. The soil of the swamp is soggy, soft, and quaking, resembling muck (Buckman and Brady, 1969). It is blue-black in color, probably from an interaction between hydrogen sulfide, detectable by smell, and iron, which produces blackish iron sulfide. The entire area is drained by the Heeia stream but it is subject to flooding at high tide.

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[2] University of Hawaii, Department of Botany, Honolulu, Hawaii 96822.

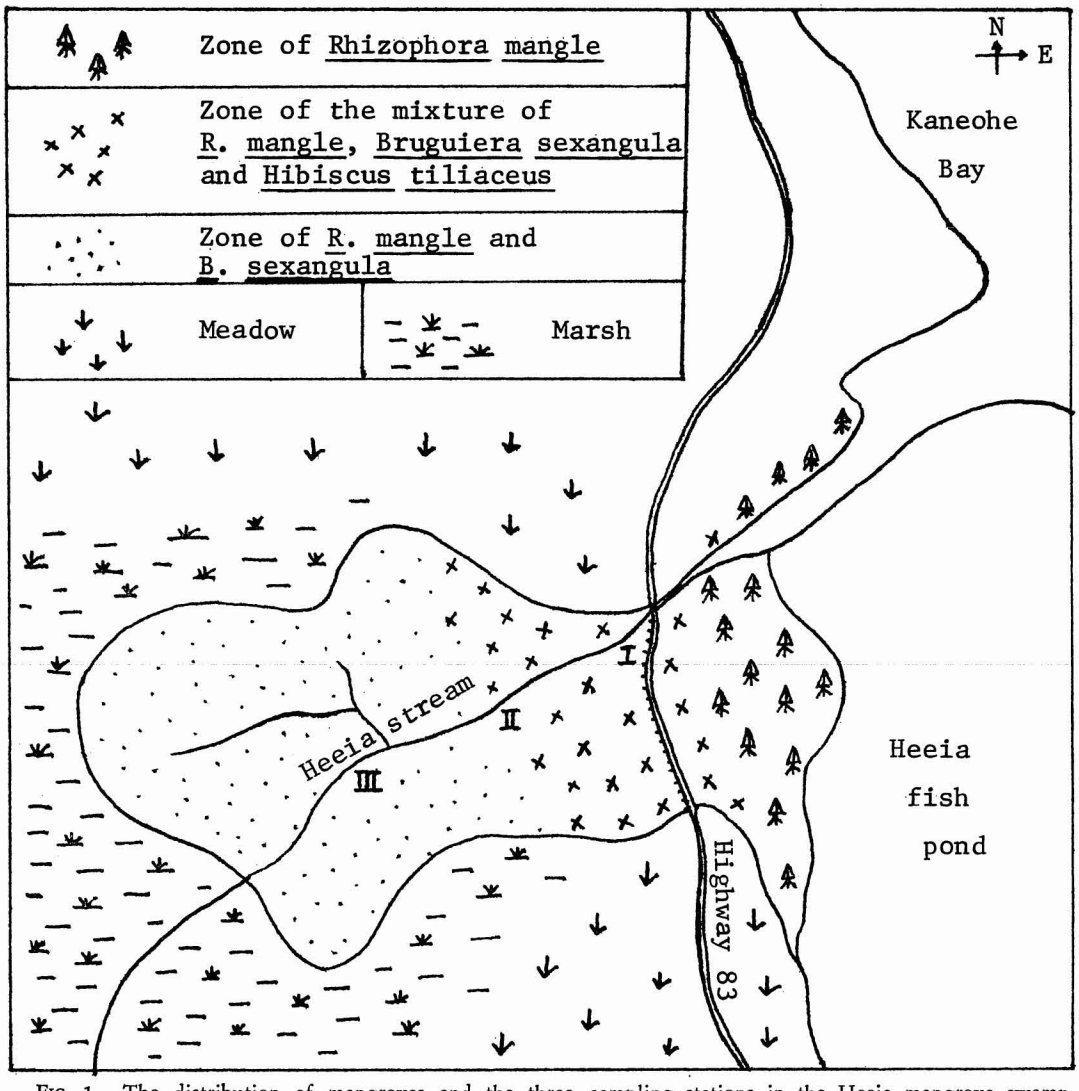

FIG. 1. The distribution of mangroves and the three sampling stations in the Heeia mangrove swamp (after Walsh, 1967, modified to reflect current conditions). I., II., III.: soil sampling stations.

MATERIALS AND METHODS

The Macrovegetation

The point center quarter and quadrat methods were used as the sampling methods (Curtis and Cottam, 1962). The point center quarter method was used to sample the trees, whereas the quadrat method was used to sample the seedlings and undergrowth (Lee, 1971).

Determination of Physical and Chemical Properties of the Soil

Three sampling stations were set up along the edge of the Heeia stream progressing from the seaward to the landward side of the swamp. Station I was situated between stations 4 and 5 previously established by Walsh (1967) on the Heeia stream, west of Highway 83 and near the bridge on the seaward side. Stations II and III were located about 100 and 200 m, respectively, landward from station I (Fig. 1). Investigations covered: soil temperature, taken at 5 inches' depth and measured by a tele-thermometer (Yellow Springs Instrument Co., model 43 TD); soil pH, measured by a Beckman glass electrode pH meter at 1:1 dilution with distilled water; soil salinity, determined

by the conductivity bridge method after Chapman and Pratt (1961); organic matter (%), determined by the Walkley-Black titration method after Jackson (1958); total nitrogen in the soil, measured by the Kjeldahl method after Jackson (1958); ammonium nitrogen and nitrate nitrogen, determined by the magnesium-oxide Devarda alloy method after Black (1965); available phosphorus, determined as H_2PO_4 by Truog's modified extract method after Ayres and Hagihara (1952); and available sulfur determined as SO_4 by a turbidimetric method according to Chapman and Pratt (1961). All the measurements were made twice: on 8 July 1968 and on 2 November 1969. In addition, oxygen content of the soil at a 4-inch depth from the surface was measured in all three stations by a Precision Galvanic cell oxygen analyzer (cat. no. 68850) on 5 April 1970.

Collection of Soil Samples and Isolation of Fungi

Soil samples were collected at all three stations with a cork borer, 10 mm in diameter, fitted with an ejector. The sampler was sterilized with 75 percent ethyl alcohol and air-dried before each sampling. Random cores of soil were extracted from an area approximately 1 foot square and to a depth of 3 inches from the surface. Adequate amounts of soil were obtained for both chemical analysis and fungal population studies. Samples were placed in sterile Nasco Whirl-Pak bags, thoroughly mixed, and transported to the laboratory immediately. Three samples at each station were collected during the period from June to July 1968.

The standard dilution plate technique was used for isolation (Johnson, Curl, Bond, and Fribourg, 1960). Microfungal populations were cultured on sodium caseinate agar (BBL no. 11626) and soil extract agar. Separate soil extracts were prepared from the soils collected at the three sites. The formula and methods of preparation for soil extract agar were those employed by Tresner, Backus, and Curtis (1954), supplemented by 30 μg/ml of chloromycetin to inhibit bacterial growth. Plates in replicates of five per dilution were prepared for each type of agar. In a preliminary plating, it was found that a dilution of 1:1000 and 1:5000 contained approximately 20 to 100 microfungal propagules per milliliter. After two to 10 days' incubation at 26° C, the fungal colonies were counted. For qualitative analysis a random selection method was used (Tresner, Backus, and Curtis, 1954). From each colony a small block of agar bearing a few hyphal tips was transferred with a sterile needle to potato dextrose agar (Difco 0013) and Emerson YpSs agar (Difco 0739). Fifty random isolations were made from each sample, making a total of 150 isolates recovered from each station. After a suitable incubation period (10 to 12 days), the cultures were sorted into apparent taxonomic entities on the basis of distinct cultural and morphological features. The original plates were incubated an additional period of 2 weeks in order to recover a maximum number of species. The numbers of isolates of all apparent entities were recorded. Final identification of the fungal isolates involved subculturing them on various media to encourage sporulation.

RESULTS AND DISCUSSION

The Macrovegetation

By the use of the methods employed, quantitative characteristics of the macrovegetation—the number of individual plants representing each species, their size, and the space they occupied in the Heeia mangrove swamp—were determined (Lee, 1971). Dominance was based on frequency and area occupied. Two true mangrove species and one freshwater mangrove (Walsh, 1967) were the dominants of the macrovegetation. *Rhizophora mangle* was distributed throughout the area. This species contributed the highest number of individuals and occupied the greatest area. The trees that dominated the mangrove environment showed a distinct and characteristic zonation. Three zones within the mangroves may be identified (Fig. 1). The seaward zone (I) at the mouth of the stream and along the coastline was dominated by *R. mangle*. The middle zone (II) was located near the highway, where *R. mangle, Bruguiera sexangula,* and *Hibiscus tiliaceus* intermingled. The inland zone (III), near the freshwater marsh, was occupied by *Rhizophora mangle* and *Bruguiera sexangula.* The distribu-

tion of *B. sexangula* depends on the amount of freshwater, according to Macnae (1966).

The Heeia mangrove swamp appears to be in a developing stage, as the tallest *Rhizophora* trees are only about 45 feet tall. West (1956) has indicated that *Rhizophora* and *Bruguiera* species can grow to over 60 feet. However, the Heeia environment seems to be favorable for ultimate mangrove development. The temperature, rainfall, tidal range, and salinity levels of the Heeia mangrove swamp all fall within ranges recognized as supporting good mangrove growth (West, 1956; Macnae, 1966; Walsh, 1967). In addition Heeia swamp lies on a sheltered shore which protects seedlings from strong waves and wind.

Physical and Chemical Soil Properties of the Sampling Stations

Characteristics of the soil at the three sampling stations are shown in Table 1. The soil was acidic and waterlogged. It had moderately high amounts of organic matter, phosphorus, and sulfur. The percentage of organic matter (33 to 36 percent) was higher than that reported by Macnae and Kalk (1962) for the mangrove swamps at Moçambique where the percentage ranged from 0.10 to 11.03. It is less, however, than that reported by Golley, Odum, and Wilson (1962) for a Puerto Rican mangrove forest where the substratum consisted of almost 50 percent organic content. The amount of total nitrogen in each station may be correlated with the amount of organic matter in the soil. The soil has a high ammonium-nitrogen content and a low amount of nitrate-nitrogen (Table 1). If the soil were in an anaerobic condition, nitrogen would be present mostly in a reduced form, as anaerobiosis is conducive to nitrate reduction and denitrification (Brock, 1966). Salinity of the soil in the landward area correlated with the great influx of freshwater from the marsh. The higher salinity of the soil at the seaward area was probably affected by tidal penetration. The large marsh behind the swamp significantly affected the salinity and the nutrients in the landward zone. Large amounts of organic matter were brought into the swamp by the water from Heeia stream. There was no significant difference between air and soil temperatures.

TABLE 1

SOIL CHARACTERISTICS AT THREE STATIONS OF HEEIA MANGROVE SWAMP, OAHU

DETERMINATION	DATE	STATION I SEAWARD ZONE	STATION II MIDDLE ZONE	STATION III INLAND ZONE
pH (1:1 Dilution)	8 Jul 1968	6.0	5.6	5.5
	2 Nov 1969	5.6	5.5	5.5
Salinity (‰)	8 Jul 1968	11	8.7	5.9
	2 Nov 1969	14	8.3	5.2
Organic Matter (%)	8 Jul 1968	33.7	33.1	35.8
	2 Nov 1969	35.5	34.6	36.4
Available Phosphorus H_2PO_4 (0.02 N H_2SO_4, ppm)	8 Jul 1968	61	65	70
	2 Nov 1969	72	98	100
Available Sulfur, SO_4 (ppm)	8 Jul 1968	120	80	100
	2 Nov 1969	140	100	120
Total Nitrogen (%)	8 Jul 1968	0.62	0.78	0.84
	2 Nov 1969	0.77	0.74	0.91
NH_4 N (ppm)	8 Jul 1968	12	13.6	12.5
	2 Nov 1969	10	12.4	11.6
NO_3 N (ppm)	8 Jul 1968	0.0	0.0	0.1
	2 Nov 1969	0.3	0.2	0.3
Oxygen content (mg/liter) (4 inches below the soil surface)	5 Apr 1970	0.0	0.0	0.0

Microfungi Isolated from the Heeia Mangrove Swamp and their Distribution

The 450 selected isolates from the three sampling stations in the Heeia mangrove swamp yielded 52 species which are listed, with their frequencies, in Table 2. These represented: Fungi Imperfecti, 47; Ascomycetes, 4; and Phycomycetes, 1. The other four isolates were nonsporulating forms, potentially making a total of 56 species (Table 2). The distribution of these microfungi in the Heeia mangrove swamp soil is given in Table 3.

The majority of the identified taxa in the mangrove swamp soil were Fungi Imperfecti. This group contributed 82.5 percent of the total isolates and 83.6 percent of the total species. Among them, a large percentage of the collections was made up of members of the Moniliales. These represented 79.2 percent of the total isolates and 80.1 percent of the total species. Others were Melanconiales, which contributed 3.3 percent of the total isolates. *Trichoderma* was the most common genus, represented by only two species but accounting for approximately 34.8 percent of the total isolates. *Penicillium,* another prevalent genus (14 species), represented 12.2 percent of the isolates. *Fusarium,* with seven species and 9.1 percent of the total isolates, was also a prominent generic taxon. Only six species of *Aspergillus* appeared in the mangrove swamp soil, contributing 3.3 percent of the total isolates. The distribution of the fungal population in the mangrove swamp revealed that eight species of Fungi Imperfecti and three species of Ascomycetes were present at all three stations (I, II, III); 10 species of Fungi Imperfecti were present in the seaward zone (I) but were not found in the other zones; 11 species of Fungi Imperfecti and one phycomycete were present in the inland zone (III) only; 11 species of Fungi Imperfecti and one species of the Ascomycetes were present in the middle zone (II) only.

TABLE 2

DISTRIBUTION OF FUNGAL GROUPS IN THE HEEIA MANGROVE SWAMP SOILS

GROUPS	NUMBER OF SPECIES	PERCENTAGE OF TOTAL SPECIES	PERCENTAGE OF TOTAL ISOLATES
Phycomycetes	1	1.7	0.6
Ascomycetes	4	7.1	15.1
Fungi Imperfecti	47	83.6	82.5
Moniliales	45	80.1	79.2
Penicillia (Excluding Ascosporic Form)	14	25.0	12.2
Aspergilli	6	10.7	3.3
Fusaria	7	12.5	9.1
Trichodermas	2	3.5	34.8
Moniliaceae (excluding Penicillia, Aspergilli, Fusaria, Trichodermas)	12	21.4	16.0
Dematiaceae	3	5.3	2.6
Stibellaceae	1	1.7	0.2
Melanconiales	2	3.5	3.3
Yeast	1	1.7	0.6
Nonsporulating Mycelia	3	5.3	1.7
Total Sporulating	52		

As shown in Table 1, the most striking feature was the almost total absence of Phycomycetes. Only one species, *Circinella simplex,* was found in the inland zone, but it was not found in the seaward zone. Four Ascomycetes, namely *Chaetomium* sp., *Penicillium vermiculatum, Pycnidiophora dispersa,* and *P. multispora,* were isolated. A relatively high number of *Penicillium vermiculatum* and *Pycnidiophora multispora* isolates was recovered from all three sampling stations. Basidiomycetes were not isolated from the mangrove swamp soil.

In the present study, a dilution plating method was used for isolating fungi. The authors agree with the frequently expressed opinion that all methods of isolating fungi are selective and that an acceptable single nonselective method is unlikely to be devised (Garrett, 1951), but the dilution plate method can be valuable and productive of significant results if its limitations are recognized (Montégut, 1960).

Swart (1958) in Africa and Rai, Tewari, and Mukerji (1969) in India have investigated soil fungi in mangrove swamps but the taxa representing the macrovegetation in these areas differ from those in the Hawaiian mangrove swamp at Heeia. Although Swart (1958) did not use the dilution plate method when working on microfungi in mangrove swamp soil in East Africa, some correlation is found between the populations he found and those occurring in the Heeia swamp soil. Rai and his coworkers

TABLE 3

ALPHABETICAL LIST OF ALL IDENTIFIED SOIL FUNGI AND THEIR FREQUENCIES OF OCCURRENCE (% OF THE TOTAL NUMBER OF FUNGI ISOLATED) AT THREE STATIONS, HEEIA MANGROVE SWAMP

	FREQUENCIES AT EACH STATION			PERCENTAGE OF TOTAL NUMBER OF ISOLATE
	SEAWARD ZONE I	MIDDLE ZONE II	INLAND ZONE III	
Aspergillus carneus (van Tieghem) Blochwitz	2.0	—	—	0.6
A. flavipes (Bain. & Sart.) Thom & Church	—	—	1.3	0.4
A. fumigatus Fresenius	2.0	—	—	0.6
A. niger van Tieghem	—	—	2.0	0.6
A. ustus (Bain.) Thom & Church	—	—	1.3	0.4
A. sclerotiorum Huber	—	1.3	—	0.4
Cephalosporium acremonium Corda	—	2.0	—	0.6
Circinella simplex van Tieghem	—	—	2.0	0.6
Cladosporium avellaneum De Vries	2.0	—	2.6	1.5
Chaetomium sp.	—	0.6	—	0.2
Cylindrocladium parvum Anderson	—	2.6	—	0.8
Fusarium bostrycoides Wollenweber & Reinking	—	2.0	—	0.6
F. dimerum Penzig	—	—	1.3	0.4
F. lateritium Nees	1.3	3.3	1.3	2.0
F. roseium Link	5.3	2.6	2.0	3.3
F. solani (Martius) Appel & Wollenweber	4.6	—	—	1.5
F. sporotrichioides Sherbakoff	—	2.0	—	0.6
Fusarium sp.	—	1.3	—	0.4
Geotrichum sp.	6.6	5.3	4.0	5.3
Gliocladium deliquescens Sopp	2.0	2.6	2.0	2.2
Graphium sp.	0.6	—	—	0.2
Humicola sp.	1.3	—	—	0.4
Leptographium lundbergii Lagerb. & Melin	—	2.0	—	0.6
Metarrhizium anisopliae (Metsch.) Sorok	1.3	—	5.3	2.2
Monosporium sp.	—	—	2.6	0.8
Monilia sp.	0.6	—	—	0.2
Penicillium corylophilum Dierckx	—	1.3	—	0.4
P. decumbens Thom	—	—	1.3	0.4
P. diversum Raper & Fennell	1.3	0.6	1.3	1.1
P. funiculosum Thom	—	1.3	2.6	1.3
P. frequentans Westling	—	1.3	—	0.4
P. janthinellum Biourge	2.0	—	—	0.6
P. lilacinum Thom	2.6	4.6	2.6	3.3
P. melinii Thom	—	—	2.6	0.8
P. ochro-chloron Biourge	2.6	—	1.3	1.3
P. oxalicum Currie & Thom	—	0.6	—	0.2
P. purpurogenum Stoll	—	—	0.6	0.2
P. simplicissimum Thom	2.0	—	—	0.6
P. variable Sopp.	0.6	1.3	—	0.6
P. vermiculatum Dangeard	1.3	2.0	12.0	5.1
Penicillium sp.	—	—	1.3	0.4
Pestalotia sp.	—	—	2.0	0.6
Pestalotia heterocornis Guba	0.6	7.3	—	2.6
Pycnidiophora dispersa Clum	2.0	1.3	3.3	2.2
P. multispora (Saito & Minoura) Thompson & Backus	6.0	10.0	6.6	7.5
Sporotrichum pruinosum Gilman & Abbott	—	3.3	—	1.1
Spicaria silvatica Oudemans	1.3	—	—	0.4
Trichoderma glaucum Abbott	16.6	8.6	8.6	11.3
T. viride Pers	24.0	22.6	22.0	23.5
Verticillium cellulosae Daszewska	—	1.3	1.3	0.8
V. sulphurellum Saccardo	2.0	—	—	0.6
Verticillium sp.	—	—	1.3	0.4
Yeast	1.3	0.6	—	0.6
Nonsporulating Mycelia	1.3	3.3	0.6	1.7

(1969) used two methods to analyze the soil microfungal populations of mangrove swamp soil in India: the soil plate method of Swart and the dilution plate method. Their results also show correlation with the Heeia swamp findings based on the dilution plate method. Basidiomycetes were entirely absent in all the mangrove swamp soils. Phycomycetes occurred in very low frequencies in all areas. Only one species, *Circinella simplex,* was found in the Heeia mangrove swamp. Ascomycetes were few, too. The majority of fungi isolated belonged to the Fungi Imperfecti. *Trichoderma,* the most common genus in the Heeia mangrove swamp soil, is well known to be ubiquitous in soil. Swart noted *Trichoderma* as one of the two most common isolates. Rai, Tewari, and Mukerji noted the presence of the genus but did not give data on its frequency. Jensen (1931) reported that *Trichoderma viride* was common in acid and waterlogged soil. Maciejowska and Williams (1963) demonstrated that *Trichoderma* develops better with high levels of soil moisture. They also noted that production and dispersal of the antagonistic effect of *Trichoderma* toward other soil microorganisms is greater in wet soils. Macanley and Griffin (1969) indicated that *Trichoderma* sp. was isolated most frequently from soil with low concentrations of oxygen. The frequent occurrence of *Trichoderma* in the mangrove swamp soil suggests that this fungus has great tolerance to its waterlogged condition and poor aeration. *Penicillium* constituted the most important genus, based on the number of species isolated. The variety of its species presented spectra fairly similar for both Hawaiian and East African mangrove swamps. *Pestalotia* species were isolated frequently in both areas.

A number of fungi not common in mangrove habitats was isolated during the study. Four were not reported in Swart's studies on the Inhaca mangrove swamp soil nor by Rai, Tewari, and Mukerji working in India, and are new to mangrove records. *Cylindrocladium, Gliocladium, Metarrhizium,* and *Geotrichum* were found commonly in the Heeia mangrove swamp.

Metarrhizium anisopliae, the species isolated from Heeia soil, causes the disease of insects known as "green muscardine" in both temperate and tropical countries. *M. anisopliae* is recorded infrequently from soil. Miller, Giddens, and Foster (1957) were the first to report the isolation of this entomogenous fungus directly from soil. Goos (1963) isolated this fungus from banana soil in Honduras. There are many varieties of insects living in the mangrove swamp with which it could be associated.

A few of the isolates are not listed in Gilman's manual of soil fungi (1957) and are rarely found in the soil habitat (Barron, 1968).

The genus *Pycnidiophora* is a plectomycetous fungus, assignable to the Eurotiales of the Ascomycetes. Two species were isolated from the mangrove swamp soil, both first records for Hawaiian soil. *Pycnidiophora dispersa* was first isolated from a diseased seedling of *Phlox drummondii* by Clum (1955). According to Goos (1963), this fungus has been found in soils from Honduras, Africa, and Pakistan. *Pycnidiophora multispora* was originally described as *Pseudeurotium multisporum* in 1955. However, Thompson and Backus (1966) transferred this fungus to the emended genus *Pycnidiophora* as *P. multispora.*

The genus *Leptographium* was erected by Lagerberg and Melin (Barron, 1968). Isolations of *Leptographium* from white pine have been reported (Hubert, 1953); it has also been associated with insects (Davidson, 1955, 1958). However, in studying the soil fungi in Ontario, Canada, Barron (1968) did not recover it from soil. According to Barron, only one authentic soil isolation is known, but, as he notes, earlier descriptions in the literature are not adequate, making it impossible to say whether or not *Leptographium* is common in soil. *Leptographium lundbergii* occurred only in the middle zone of the Heeia mangrove swamp soil with a low frequency.

From many sources, it seems evident that species composition of fungal community is correlated with habitat. It has been determined that soil fungi are influenced by temperature, pH, moisture, and organic content (Alexander, 1961). Brown (1958) supported the concept of microfungal sensitivity to the soil environment by finding qualitative and quantitative differences of microfungi in acidic and alkaline dunes. Tresner, Backus, and Curtis (1954),

studying the soil microfungal relations with the hardwood forest continuum in southern Wisconsin, determined that variation in the microfungi matched variation in the higher plant cover. Herr (1957) and Kommedahl and Brock (1954) demonstrated that the vegetation plays a role in the makeup of the microfungi, both in density and in species composition. This selective action may be the result of specific root excretions; or decomposing, sloughed-off tissue may promote or inhibit the growth and activity of various groups of fungi.

The microfungi present in the mangrove swamp may be characteristic of this special ecosystem. Organic matter content, nutrient levels, oxygen content, pH, and salinity are probably the most important environmental factors controlling the nature and distribution pattern of microfungi in the mangrove swamp soil. The composition of the attendant higher vegetation and each of the major soil factors must be considered in relating environmental factors with specific fungal communities. The nutrient level is probably not a factor limiting the microfungal composition in the mangrove swamp soil as the organic matter, phosphorus, and total nitrogen were present in amounts considered satisfactory for fungal growth. On the other hand, its waterlogged condition, its lack of aeration, and the salt content of the soil may be factors limiting distribution. Species abundantly present in the inland zone displayed decreasing numbers with progression through seaward zones, indicating sensitivity to the salinity level (e.g., *Penicillium vermiculatum*). The fungi isolated from the seaward zone can tolerate the salinity level of seawater (e.g., *Fusarium roseum* and *Trichoderma glaucum*) but were less frequently represented in the inland zones. In addition, the presence of hydrogen sulfide gas in the mangrove swamp may result in the absence of certain fungi from the soil in the swamp since hydrogen sulfide gas is very toxic to fungi (McCallan and Setterstrom, 1940). Brock (1966) indicated that hydrogen sulfide gas in bogs is a limiting factor for aerobic microorganisms and a metabolite for certain anaerobes. Specific limiting factors probably could be demonstrated experimentally for individual species, but the soil microfungal population in the mangrove swamp as a whole undoubtedly is influenced by interacting factors such as physical and chemical characteristics of the environment, nature of the substrate, and interactions with other organisms.

SUMMARY

An ecological survey of the macrovegetation and soil microfungi was carried out in the Heeia mangrove swamp, Oahu, Hawaii. *Rhizophora mangle* and *Bruguiera sexangula* were the two dominant mangrove genera in the mangrove swamp. Three zones in the macrovegetation were discernible. The environment of the Heeia area was found to be favorable to ultimate mangrove development.

Physical and chemical conditions in the Heeia mangrove swamp were determined. The soil was in an acidic, brackish, and waterlogged condition. The salinity decreased from the seaward zone to the inland area. The soil had moderately high amounts of organic matter, phosphorus, and sulfur. The role of the large marsh behind the swamp was significant, especially in its effect on the salinity. The seaward area was influenced by the tidal flux. Chemical conditions of the seaward area and the inland area showed only slight differences except for the salinity of the soil.

The majority of the colonies and species of fungi isolated belonged to the Fungi Imperfecti. *Trichoderma* was the most common genus, accounting for almost 34.8 percent of the total isolates. A comparatively high proportion of the species encountered was Penicillia, with 14 species (excluding ascosporic forms) representing 12.2 percent of the total isolates. Phycomycetes were almost totally absent in the soil. Basidiomycetes were entirely absent in the mangrove swamp soil. Each of the three areas sampled had a typical community of species, none of which occurred at the other two sites. However, a large population was common to all three sites. A comparison of the microfungal communities occurring in the Heeia mangrove swamp soil with those of mangrove swamp soils on the island of Inhaca, East Africa, and India reveals that the three fungal communities present a fairly similar picture. Some of the

environmental factors which possibly control the nature and distribution of the fungal population in the Heeia mangrove swamp soil are salinity, a waterlogged condition, and the presence of hydrogen sulfide. These conditions are common to the widely separated geographic areas compared, indicating a common ecological habitat for mangrove microfungi.

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